

Use of Bagasse as a Feed Input to Semi-Intensive Shrimp Growout Ponds

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Abstract

Efforts to reduce the cost of growout feeds for aquaculture have traditionally focused on the use of agricultural wastes as direct or indirect nutritional supplements to support semi-intensive production levels. The merits of a low cost, sugar cane bagasse-based feed for semi-intensive production of *Penaeus vannamei* were evaluated. Shrimp averaging 0.24 g each were stocked into 200 m² earthen ponds at 20/m² and cultured for a 12 week period. Two bagasse-based feed treatments, a manure-based treatment and a no-feed input control, were compared in replicate ponds. One bagasse treatment (artificial manure) was designed to mimic manure and stimulate autotrophic and heterotrophic growth. The other bagasse treatment (bagasse alone plus inorganics) was designed to stimulate primarily autotrophic growth. Both bagasse treatments produced average growth rates of 0.78 g/wk, which were significantly greater than that of the manure treatment (0.57 g/wk). Lack of difference between the two bagasse treatments suggests that additional supplements used in making artificial manure probably were unnecessary to the nutrition of the shrimp. At harvest, bottom organics in the bagasse-fed ponds were at least twice as great as manure-fed ponds, and may have contributed to the lower survival associated with these treatments.

Feed costs can represent the largest single operating expense in commercial aquaculture (Bauer et al. 1983; Shang and Costa-Pierce 1983). Efforts to reduce the cost of growout feeds for aquaculture have traditionally focused on the use of agricultural wastes as direct or indirect nutritional supplements. Waste products have been used as an ingredient of formulated feeds or as a fertilizer to enhance natural productivity of ponds. Considerably more research has been conducted on using wastes as pond fertilizers, especially in freshwater culture systems (Schroeder 1978; Hepher and Pruginin 1981). Fertilization provides available forms of nitrogen (N) and phosphorus (P) which stimulate and support the autotrophic base of the food web (Noriega-Curtis 1979). Many heterotrophs feed on autotrophs (Parmley and Geiger 1985) and both, in turn, serve as food for aquatic insects and invertebrates (Zur 1981). Organic matter in sediments also becomes substratum for bacteria and protozoa (Fenchel and Jorgensen 1977; Newell

1984) which also can serve as food for fish and shrimp (Schroeder 1983).

In particular, the age-old practice of fertilizing ponds with manures has received renewed emphasis by some aquacultural researchers (Wohlfarth and Schroeder 1979). Until recently, there was little information on the growth of marine shrimp in fertilized ponds. Rubright et al. (1981) studied phytoplankton and zooplankton populations and overall production of *Penaeus stylirostris* in ponds fertilized by inorganics alone or in combination with a commercial shrimp feed. The following studies conducted at The Oceanic Institute, Hawaii, indicate that inputs of feedlot manure alone can support pond production of *Penaeus vannamei*. Lee and Shleser (1984) compared the effect of cattle manure, manure plus sodium nitrate, and a commercial feed on growth of *P. vannamei*. Weekly growth rates and survival were similar in ponds receiving either manure with fertilizer or those receiving feed exclusively. They concluded that *P. van-*

namei could be cultivated in cow manure-enriched ponds. Wyban et al. (1987) studied effects of stocking density on *P. vannamei* growth in manure-fertilized ponds. Highest production was achieved at a stocking density of 15 shrimp/m², and they concluded that weekly additions of manure to ponds could support commercial levels of production.

The use of manure in shrimp aquaculture ponds, however, is not without constraints. Manures are not always readily available in the vicinity of shrimp farms, and some North American consumers perceive a health risk when animal products are grown in association with livestock manures. Although Wyban et al. (1987) did not identify any harmful microbiological organisms in shrimp grown in manure-treated ponds, consumer attitudes could still limit acceptance of such products.

Proximate analyses of feedlot manure indicated that a high fiber by-product could be used as the base material for formulating a manure substitute. The use of fibrous waste materials as pond feed components has shown promise in freshwater prawn culture (Moore and Stanley 1982; Miltner et al. 1983). Moore and Stanley (1982) concluded that high cellulosic-containing corn silage, in combination with commercial prawn pellets, could effectively replace up to 50% of the commercial feed input without affecting growth of *Macrobrachium*. Sugar cane bagasse, because of its low cost and general availability in shrimp-growing latitudes, was an attractive candidate for a pond supplement. This study was designed to evaluate the use of two low cost, bagasse-based substitutes for manure fertilization in semi-intensive shrimp production.

Materials and Methods

The manure treatment consisted of weekly inputs of dried feedlot manure equivalent to 1,500 kg/ha. The manure was added to approximately 20 L of seawater, stirred vigorously, and then cast out over the surface of the pond in five aliquots.

The artificial manure (bagasse-AM) formulation treatment was based on the nutrient profile of dried feedlot manure. The fiber component was sugar cane bagasse which had been formed into 3 mm dia × 8 mm pellets using a California Pellet Mill (Hamakua Sugar Mill, Hamakua, Hawaii). The fiber content of bagasse is described in Hilton and Hoskins (1985). Molasses, blood meal, cod liver oil, sodium nitrate, and potassium phosphate were then added to these pellets and blended in a ribbon blender. Specific quantities of the non-bagasse ingredients were added so the entire mix could be considered one feed balanced on an "as-fed" basis to be iso-fibrous, iso-nitrogenous, iso-phosphorus, and iso-caloric with dried feedlot manure. To the extent possible, this treatment was also balanced to contain amounts of crude protein, lipids and minerals equivalent to manure (Table 1). With the exception of the inorganics (sodium nitrate and potassium phosphate), all ingredients were mixed to form the core feed which was added to ponds weekly. The inorganic components were subdivided and added daily to the ponds in equal amounts after having been dissolved in water, and dispersed over the pond surface.

The other bagasse treatment (bagasse-NP) consisted of adding bagasse pellets alone on a weekly basis, and daily additions of inorganic nitrogen (N) and phosphorus (P). Total inputs were calculated to be iso-nitrogenous, iso-phosphorus and iso-fibrous with bagasse-AM and feedlot manure (Table 1). This treatment was formulated so the bulk of N and P could be solubilized, thereby stimulating primary productivity in the water column. In both bagasse-based treatments, daily additions of inorganics were suspended (on a per pond basis) when a Secchi disk reading of 30 cm or less was recorded at 0900 h.

After an initial two week drying out period, during which loose, dry floc material was removed, eight 200 m² (filled surface area) earthen (clay bottom) ponds were filled with seawater (35 ppt) supplied from a well.

TABLE 1. *Composition of bagasse-based feeds.*

Bagasse-AM^a	
Bagasse pellets	15.26 kg
Blood meal	3.10 kg
Molasses	3.00 kg
Mineral mix	1.00 kg
Cod liver oil	0.03 kg
Added separately as a liquid mix	
NaNO ₃	0.10 kg
NaPO ₄	0.01 kg
Bagasse-NP^a	
Bagasse pellets	15.26 kg
Added separately as a liquid mix	
NaNO ₃	0.46 kg
NaPO ₄	0.08 kg

^a Balanced for standard weekly manure input of 30/kg pond (1,500 kg/ha).

After two weeks, *P. vannamei* (0.24 g each) were stocked at 20 shrimp/m². This delay ensured an adequate phytoplankton bloom prior to stocking. Each of the four pond treatments was replicated twice. Water exchange rates were approximately 40% per day. No commercial feeds were added to any of the ponds throughout the study.

Water quality parameters (temperature, pH, DO, Secchi depth) of each pond were recorded twice daily at 0900 and 1600 h. The mean wet weight of 70 shrimp from each pond was determined every other week, except for weeks 6 and 10, when only 35 shrimp were weighed. Shrimp were harvested after twelve weeks.

Accumulation of organic matter in the ponds was determined on week 12 prior to harvest. A clear 1 in. diameter plexiglass tube was pushed into the pond sediments until it slightly penetrated the underlying hard clay layer. The tube was capped, carefully removed from the pond bottom, and the height of organics was measured. Five samples were obtained at equidistant locations along a diagonal transect extending from the deep to shallow end in each of the eight ponds. This sampling was conducted from a large surfboard to minimize disturbance of pond sediments.

Treatment effects on shrimp size at harvest, weekly growth, survival, yield, and organic matter accumulation were compared using a one-way ANOVA and a priori designed multiple constants (Sokal and Rohlf 1981). Yield and production data were adjusted to account for biweekly sampling weight loss.

Results

Mean values of the water quality parameters are presented in Table 2. Comprehensive water quality data and microbial dynamics associated with this study are provided in Visscher and Duerr (1991) and Weisburd and Laws (1990). Control ponds had greater daily Secchi depths than the other treatments and DO levels were accordingly lower for evening (1600 h) determinations. Evening DO levels were generally greater in the two bagasse-based treatments (Table 2).

One consequence of using a feed material containing large amounts of cellulosic-type components is that sediment matter accumulates on the pond bottom. Fig. 1 presents the amount of sediment accumulation observed above the clay bottom in each pond on the last week of the trials. Accumulations of bottom organics in ponds receiving the two bagasse-based feeds were significantly greater ($P < 0.01$) than in the manure and control treatment ponds.

As presented in Fig. 2, treatment effects upon shrimp growth were evident after week 6. By week 8, shrimp growth in the control ponds decreased dramatically, while shrimp in all other treatments continued growth at a more rapid pace. Mean wet weights for week 8 reveal that the shrimp from the two bagasse-based treatments (NP = 5.6 g, AM = 5.2 g) were larger than shrimp from manure-treated ponds (4.1 g) which, in turn, were larger than shrimp from the control ponds (3.8 g). An equivalent biweekly trend among shrimp weights from the various treatments continued through harvest with treatment effects becoming very pronounced by week 10 (Fig. 2).

TABLE 2. Mean \pm standard error (N = 84) in temperature, pH, DO and Secchi visibility at 0900 and 1600 h in all ponds during the 12 week period.

Treatment	Time	C	pH	DO (mg/L)	Secchi (cm)
Bagasse-AM	0900	28.2 \pm 0.1	8.0 \pm 0.1	6.8 \pm 0.2	45 \pm 2
	1600	31.4 \pm 0.1	8.5 \pm 0.1	14.9 \pm 0.4	41 \pm 1
Bagasse-NP	0900	28.2 \pm 0.1	8.1 \pm 0.1	6.8 \pm 0.2	40 \pm 1
	1600	31.4 \pm 0.2	8.5 \pm 0.1	14.4 \pm 0.4	39 \pm 1
Manure	0900	28.1 \pm 0.1	7.9 \pm 0.1	6.6 \pm 0.1	48 \pm 2
	1600	31.4 \pm 0.1	8.3 \pm 0.1	12.1 \pm 0.3	44 \pm 2
Control	0900	28.1 \pm 0.1	7.8 \pm 0.1	6.6 \pm 0.1	63 \pm 1
	1600	31.5 \pm 0.2	8.2 \pm 0.1	10.8 \pm 0.2	58 \pm 1

Table 3 presents the mean values for shrimp weights at harvest, yields, calculated weekly growth rates, survival, and production values by treatment. Mean wet weight of shrimp from ponds receiving bagasse-NP was 9.69 g, from bagasse-AM ponds 9.41 g,

from manure-fed ponds 7.05 g, and control ponds 4.90 g. Shrimp weights between the two bagassed treatments were not significantly different ($P > 0.05$) from each other but, as a group, were significantly larger ($P < 0.05$) than shrimp from either the ma-

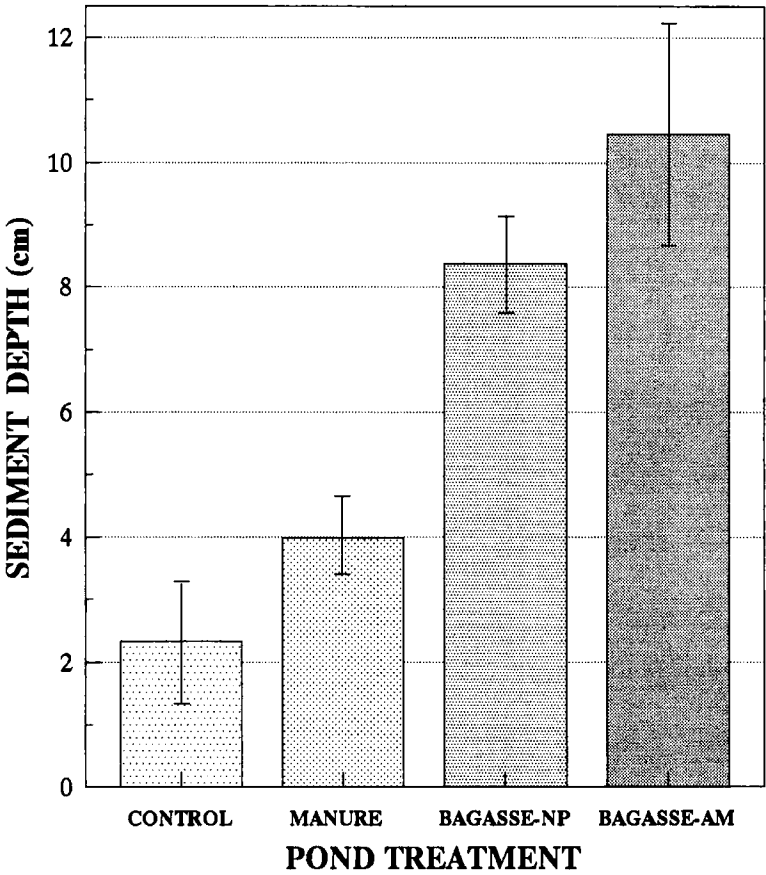


FIGURE 1. Accumulation of organic sediments in the pond bottoms at harvest. Values are means \pm SE, N = 5.

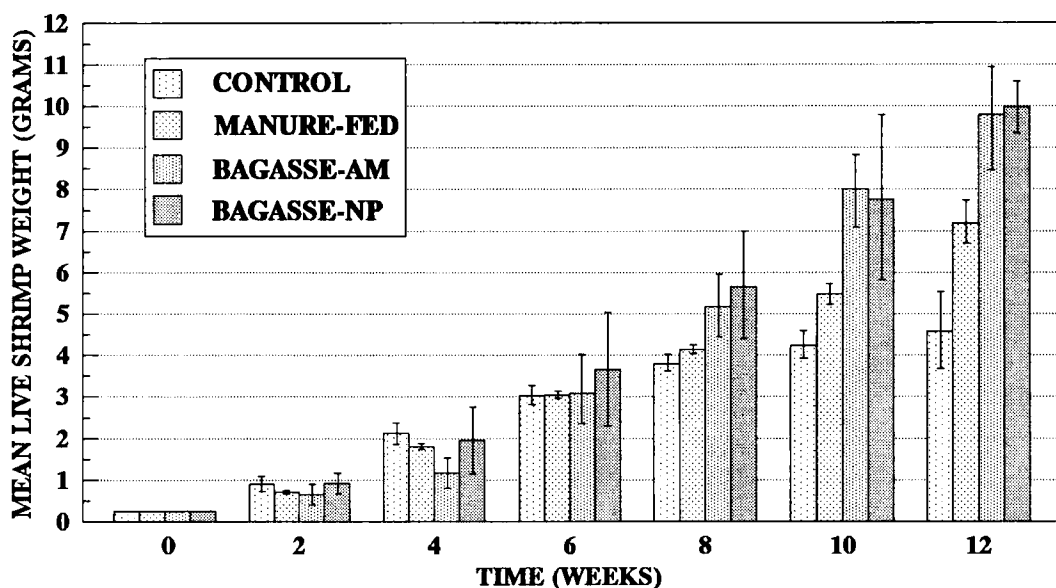


FIGURE 2. Shrimp weights at biweekly intervals as affected by pond treatment. Values are means \pm SE, N = 70, except for week 6 and 10, where N = 35.

nure-treated or the control ponds. Likewise, average weekly growth between the two bagasse treatments (NP = 0.79 g, AM = 0.76 g) were not significantly different from each other, but as a group, exhibited significantly greater growth than shrimp from either manure-treated (0.57 g) or control ponds (0.39 g). Shrimp survival was not significantly different between any of the pond treatments. However, a trend toward lower survival appeared evident in the bagasse-treated ponds (NP = 65%, AM = 60%) compared to the manure-treated (76%) and the control ponds (74%).

As a result of large within-treatment errors, no significant differences ($P > 0.05$) in overall shrimp production were indicated between any of the treatments (Table 3). Ponds receiving bagasse-NP produced 1,267 kg/ha, ponds receiving bagasse-AM produced 1,135 kg/ha, ponds receiving manure produced 1,071 kg/ha, and control ponds produced 728 kg/ha after 12 weeks of grow-out.

Feeding costs for the bagasse-NP treatment and the manure treatment were essentially equivalent when calculated on a

per kg shrimp growth basis (\$0.58/kg and \$0.59/kg, respectively). In contrast, the cost of feeding a commercial diet to produce *Penaeus vannamei* in the same earthen ponds (feeding rates extrapolated from Experiment II, Lee and Shleser 1984) was approximately \$2.17/kg shrimp growth. It should be noted that the earlier study employed a much lower stocking density (8.2 shrimp/m²), larger initial shrimp (4.9 g), and achieved more rapid growth (1.13 g/wk) than the present study.

Discussion

Growth rate of shrimp in the bagasse treatments was superior to that achieved in this and previous studies using manure-based fertilization at 20 animals/m² (Lee and Shleser 1984; Wyban et al. 1987). A commercial shrimp feed used in similar, low intensity culture conditions has been estimated to produce 12–14 g shrimp in 12 weeks (Lee and Shleser 1984). In comparison, almost 10 g shrimp were obtained in 12 weeks using bagasse-based feeds in this study.

Control ponds never maintained algal

TABLE 3. The effect of pond treatment on final shrimp weights, yields, growth rates, survival, and production.^a

Treatment	Weight (g) ^b	Yield (kg)	Growth (g/wk)	Survival (%)	Production (kg/ha)
Bagasse-NP	9.69 ± 1.34	26.30 ± 4.65	0.79 ± 0.11	65 ± 1	1,267 ± 232
Bagasse-AM	9.41 ± 0.62	23.66 ± 3.46	0.76 ± 0.05	60 ± 14	1,135 ± 173
Manure	7.05 ± 0.21	22.38 ± 3.78	0.57 ± 0.02	76 ± 13	1,071 ± 189
Control	4.90 ± 1.14	15.52 ± 3.90	0.39 ± 0.10	74 ± 5	728 ± 195

^a Data are presented as means ± SD.^b Live wet weight.

densities high enough to cause "crashes" and consequent oxygen depletion. Growth of shrimp in the control ponds was most likely derived from low levels of pond biota supported by residual organics left in the clay from past feeding trials, as well as that provided by incoming well water.

Ponds that were part of the manure and bagasse-AM treatments had algal crashes at least once weekly after week 4, whereas crashes in the bagasse-NP ponds occurred infrequently. The lack of phytoplankton crashes might be explained by greater control of phytoplankton growth in the bagasse-NP treatment, through N and P additions determined by the Secchi reading. Although this does not imply a total ability to control phytoplankton blooms, small inputs of N and P daily were certainly helpful in maintaining more consistent daily Secchi visibilities. After crashes occurred, ponds receiving either of the bagasse-based feeds appeared to recover their blooms more quickly than the manure-treated ponds. Measurements of natural productivity revealed that suspended biomass in the various ponds reached distinct plateaus of 2, 24, and 50 × 10⁸ cells per liter for the control, manure and bagasse-fed ponds respectively (Visscher and Duerr 1991).

As reported by Caillouet et al. (1976) in studies on the growth of *P. duorarum* fed cellulosic-laden plant by-products, the greatest accumulations of organic-rich sediments occurred in the ponds receiving bagasse-based feeds. Sediment formation was anticipated because bagasse is composed of large quantities of lignin and cellulose, both

of which are relatively biologically inert. After week 8, these accumulations contained anoxic zones, and, at harvest, all bagasse-fed ponds emanated strong hydrogen sulfide odors. Although the shrimp survived in these sediments, the effects on growth are unknown. Possibly, the amount of bagasse (fiber) material introduced into the ponds exceeded the necessary levels. Daily N and P inputs could have continued without the bagasse pellets, depending on the Secchi visibility criterion. This approach may have been more effective because only substrate may be necessary for maintaining benthic heterotrophs, whose nutritional needs can be satisfied by dissolved organic matter (Findlay and Meyer 1984; Martens 1984; Paerl 1984).

Because the bagasse-AM feed performed no better than bagasse-NP, it is assumed that the organic supplements did not contribute to the actual nutrition of the shrimp in the ponds fed bagasse-AM. The effects of the exclusive addition of inorganics versus in combination with bagasse, should also be investigated, especially relative to reducing the fiber loading rate.

The results of this study suggest that modest shrimp growth, at least to the 10 gram size animal, can be achieved at semi-intensive stocking densities using very low-grade nutrient inputs. These nutrients appear to cycle first through the autotrophic and heterotrophic communities (Phillips 1984). There was at least an indication that stability and biomass of these communities was positively related with shrimp growth. Based on these findings, it appears evident that a

bagasse-NP type of feed is not only an attractive alternative to manure, it also can serve as a cost-effective alternative to commercially formulated low intensity shrimp feeds. It would be interesting to determine at which point the addition of more traditional shrimp feeds would be needed to boost growth. This could occur in conjunction with the use of feed inputs as described in this paper, even before the 10 gram size is reached.

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